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CROP TOLERANCE AND RESPONSE TO SEED-ROW PLACED PHOSPHORUS FERTILIZER

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Crop Tolerance and Response to Seed-Row Phosphorus Fertilizer

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Abstract

The objective of the study was to determine how seed-placed phosphorus fertilizer (12-51-0) affected emergence, early plant P nutrition and growth for six crops with limited information: canary seed, mustard, chickpea, pinto bean, alfalfa and brome grass in comparison to four crops with considerable research information available: wheat, canola, flax and pea

The majority of crops tested in the growth chamber with alternate wetting and surface drying showed no negative impact on seed germination and emergence with seed-placed P fertilizer at rates of 20 kg P_2O_5 ha^{-1} or less. Optimum conditions of soil moisture generally produced more tolerance to seed-placed P.

For wheat, canary seed, canola and pea, the placement of small amounts of P fertilizer in the seed-row typically resulted in a doubling of P uptake by the plant in the first four weeks of growth compared to the unfertilized control.

TECHNICAL REPORT

BACKGROUND and OBJECTIVES

Seed-placed phosphorus fertilization is usually one of the most efficient means for applying phosphorus, which normally results in better response than surface-applied with incorporation. Lauzon and Miller (1997) reported that early season corn and soybean shoot-P concentrations are increased with increasing soil test P and were increased with seed-placed P regardless of soil test P. However, the germination and emergence of crop seeds can be reduced by seed-placed phosphate fertilizer as some crop seeds are especially sensitive to fertilizer salts. Providing guidelines for maximum safe rates of fertilizer P with seed is essential for achieving maximum benefit from seed-row placement of P fertilizer.

General guidelines for maximum safe rates of seed-row P have been developed on the prairies for cereals, canola, flax, fababean, lentil, and pea for a narrow (six to seven) inch row spacing. The diversity of crops grown in Saskatchewan now has increased, and there is a need for information to create similar guidelines for other crops that have become popular such as canaryseed, mustard, chickpea, dry beans (pinto beans) as well as forages including alfalfa and brome grass. There is

also a need to examine tolerance for the low seed-bed disturbance configurations that now commonly operate on row spacings wider than 6 to 7 inches.

The objective of this study is to determine how seed-row placed P at different rates influences germination, emergence, early P uptake for six crops with limited information: canary seed, mustard, chickpea, pinto bean, alfalfa and bromegrass in comparison to four crops with considerable research information available: wheat, canola, flax & pea using an opener-row spacing configuration (10% seed bed utilization) typical of today's low disturbance direct seeding equipment.

MATERIALS AND METHODS

Soil, Fertilizer and Crop Seeds

The soil used in this study was collected at a depth of 0-15 cm in May of 2004 from a field in the Brown soil zone in south-central Saskatchewan near Mawer, where the soil is mapped as Haverhill association of loamy texture. The field had never received phosphorus fertilizer and had been in alfalfa for the last 10 years. After collection, the soil after collecting was mixed thoroughly in a soil mixer and stored in field-moist condition before use. For measuring basic soil properties, a sample was collected from the mixed soil, and then air-dried, crushed, passed through 2-mm sieve and stored at room temperature. Texture was estimated by hand. Electrical conductivity (EC) and pH were measured using 1:1 soil:water suspension. Organic C was measured using Leco carbon analyzer. Available P was extracted by modified Kelowna method (Qian at al., 1994). Selected soil characteristics are summarized in Table 1.

Table 1. Some characteristics of the soil for seed-placed P evaluation.

Soil	pH	EC mS cm^{-1}	Texture	Organic C g kg^{-1}	Available P* kg ha^{-1}
Haverhill	7.4	1.04	loamy	20.8	18.0

*measured by modified Kelowna method

The fertilizer phosphorus source used was commercial fertilizer grade monoammonium phosphate (12-51-0). Ten crops were chosen for this study: hard red spring wheat, argentine canola, yellow peas, flax, canaryseed, oriental mustard, kabuli chickpea, pinto bean, alfalfa and brome grass. Seeds of the ten crops were collected at the same time. The crops were placed into two categories: Crops with better established responses to P fertilization (Class 1) and Crops with limited information (Class 2) as shown in Table 2.

Table 2. The ten crops tested in the study

Crop	Variety	Seed Rate kg ha^{-1}
(1) With better established responses:		
HR Spring Wheat	Prodigy	84
Argentine Canola OP non HT	Sprint	6
Yellow Field Pea	Carneval	180
Flax	CDC Valor	35
(2) With limited information:		
Canaryseed	Common Itchless	40
Oriental Mustard	Cutlass	11
Kabuli Chickpea	Xena	140
Pinto Bean	Pintium	114
Alfalfa	Beaver	10
Bromegrass	Knowles	40

Growth Chamber Study

Mixed soil was placed into flats approximately one meter long, 15 cm wide and 15 cm deep. The soil added to the flats was field-moist and further water was added to bring the soil to field capacity. There are five rates of fertilizer treatments: 0, 10, 20, 30, 40 kg P_2O_5 ha^{-1} with four replications. A seeding tool was manufactured to simulate a low-disturbance knife or hoe type

opener with a seed bed utilization of 10% (1 inch spread and 10 inch row spacing) and on-row packing. This tool was used to place the seed at the appropriate depth along with monoammonium phosphate fertilizer. Rows of approximately 0.5 meters in length were created in the flats to provide a replicate for each crop and P fertilizer rate.

A period of four weeks following seeding and fertilizing was set for assessing seed emergence and plant growth. Emergence counts were made once every 3-5 days after planting. The data in Table 3 and 4 is the total emergence after 20 days. The flats of soil were kept near field capacity by surface watering once every day or 2 or 3 days as required to simulate rainfall. However, high airflow in the chambers was used to simulated drying in between watering as would occur in the field. Growth chamber conditions were 15°C temperature with 18 hour day length and 6 hour night period. After 4 weeks, the above ground portions of the plants in the flat were harvested. The plants were then dried, weighed for dry matter yield determination and measured for P concentration and N concentration by colorimetry using autoanalyzer after sulfuric acid-peroxide digestion using a temperature-controlled digestion block (Thomas et al. 1967). Plant P uptake was then calculated and expressed as grams per kilogram of plant tissue.

Laboratory Study

A parallel study was conducted in the lab. The method of seeding and fertilizer placement were the same as those done in the growth chamber. The purpose for this part of the study was to examine germination and emergence under optimum conditions of soil moisture, where the soil moisture was kept constantly at close to field capacity. This is in contrast to the growth chamber study where field conditions of alternate wetting followed by surface drying were simulated. Owing to greater expected tolerance to seed-placed fertilizer under the better moisture conditions of the laboratory study, two additional higher rates of P fertilizer were included. As only emergence rates were measured, wider (45 cm) but shallower (8 cm) trays were chosen. The tray lengths were approximately the same as the flax (one meter long). In each tray, 3 rows were established for

plant growth. Mixed soil was placed into trays and a total of seven rates of fertilizer treatments were used with four replications: 0, 10, 20, 30, 40, 60, 80 kg P_2O_5 ha^{-1} as 12-51-0.

Trays of soils were kept near field capacity by surface watering once every 2 days to maintain soil moisture. As soil moisture was kept relatively constant and temperature in the lab was higher than that in the growth chamber, germination was faster and better than in the growth chamber. Thus, a period of 10 days following seeding and fertilization was sufficient enough for assessing seed emergence. Emergence counts were made once every 3-5 days after planting. The data in Table 5 and 6 is the total emergence after 10 days.

RESULTS & DISCUSSION

Effect of P Fertilizer Rate on Emergence Counts

In the growth chamber study there was no significant negative impact of seed-placed P on emergence of wheat, canola, flax, canary seed, pinto bean, or chickpea over the range of rates examined, but a negative effect was observed at rates above 10 kg P_2O_5 ha^{-1} for yellow pea and alfalfa, 20 kg P_2O_5 ha^{-1} for mustard, and 30 kg P_2O_5 ha^{-1} for bromegrass (Tables 3 and 4).

Table 3. Emergence as affected by different rates of P fertilizer for wheat, canary, canola, mustard and flax in the growth chamber study

Rate of fertilizer kg P_2O_5 ha^{-1}	Wheat Counts	% E* %	Canary Counts	% E* %	Canola Counts	% E* %	Mustard Counts	% E* %	Flax Counts	% E* %
0	11.8a	98a	20.5a	93a	11.5a	96a	9.3a	62a	9.3a	46a
10	11.5a	96a	18.3b	83b	11.5a	96a	7.7a	51a	9.0a	45a
20	11.3a	94a	19.0a	86ab	10.6a	88a	7.8a	52a	9.3a	47a
30	11.5a	96a	18.0b	82b	11.3a	94a	5.3b	35b	10.3a	51a
40	11.3a	94a	19.3ab	88ab	11.3a	94a	5.0b	33b	8.5a	43a

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
%E (% Emergence) refers to % of planted seeds that emerged over 20 days

Table 4. Emergence as affected by different rate of P fertilizer for bromegrass, alfalfa, pinto bean, chickpea and yellow pea in the growth chamber study

Rate of fertilizer kg P_2O_5 ha^{-1}	Bromegrass Counts	% E* %	Alfalfa Counts	% E* %	Pinto bean Counts	% E* %	Chickpea Counts	% E* %	Yellow pea Counts	% E* %
0	15.0a	50a	14.8a	74a	6.5a	81a	5.0a	63a	7.3a	91a
10	14.0ab	47ab	15.5a	78a	6.0a	75a	4.8a	59a	7.5a	94a
20	13.3ab	44ab	12.3b	61b	6.3a	78a	4.8a	59a	5.0b	63b
30	14.3a	48a	10.5b	53b	7.0a	88a	4.0a	50a	4.3b	53b
40	7.8b	26b	10.3b	51b	6.0a	75a	4.5a	56a	4.0b	50b

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
* %E (% Emergence) refers to % of planted seeds that emerged over 20 days

The high sensitivity of yellow peas to seed placed P has been documented previously . Of interest is the low tolerance of mustard, bromegrass and alfalfa. The canola and flax was more tolerant of seed-placed P than expected. However, caution must be used in interpreting these results. In the growth chamber, while some moisture stress through soil drying is simulated, additional stresses that may occur in the field such as disease, low seed vigor etc. are not reflected in the trial. As well, this experiment only evaluates seed-placed MAP alone, not in combination with some seed-placed N and K as may be used in the field. However, the trend today is moving towards putting P in the seed-row and banding the N away from the seed-row.

Table 5. Emergence as affected by different rates of P fertilizer for wheat, canary, canola, mustard and flax from the laboratory study

Rate of fertilizer kg P_2O_5 ha^{-1}	Wheat Counts	% E* %	Canary Counts	% E* %	Canola Counts	% E* %	Mustard Counts	% E* %	Flax Counts	% E* %
0	11.8a	98a	20.0a	91a	11.5ab	96a	11.0a	73a	13.8a	69a
10	11.3ab	94ab	19.5b	89a	11.8a	98a	10.5a	70a	12.5ab	63ab
20	11.5a	96a	19.3a	88a	10.8ab	90ab	9.8a	65a	12.8ab	64ab
30	11.3ab	94ab	18.3ab	83ab	10.0b	83b	6.5b	43b	11.3b	56b
40	11.0ab	92ab	18.5a	84a	8.3c	69c	5.0b	33b	8.8c	44c
60	10.3b	85b	15.8b	72b	5.8d	48d	1.8c	12c	4.5d	23d
80	9.0c	75c	12.3c	56c	5.5d	46d	1.0c	7c	2.0e	10e

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
* %E (% Emergence) refers to % of planted seeds that emerged over 10 days

As predicted, higher emergence rates were generally achieved in the lab study (Tables 5 and 6) than in the growth chamber. This likely is a result of relatively constant soil moisture maintained near field capacity in the lab study, whereas surface drying occurring between intermittent wetting in the growth chamber would aggravate the salt effect of the fertilizer (Tables 3, 4, 5, and 6). In the lab study, the negative impact of seed-placed P on emergence was observed above 40 kg P_2O_5 ha^{-1} for wheat (Table 5) and chickpea (Table 6). The effect on chickpea was severe above 40 kg P_2O_5 ha^{-1} . Wheat is tolerant to 40 kg P_2O_5 ha^{-1} and is one of the most tolerant crops. Bromegrass in the lab study showed more tolerance than in the growth chamber, and along with canaryseed, did not show a large negative impact until the P fertilizer rate reached 60 kg P_2O_5 ha^{-1} and above, like wheat and chickpea (Tables 3, 4, 5, and 6). Alfalfa in the lab study (Table 6) also showed less injury than in the growth chamber, with a negative impact when P rate exceeded 20 kg P_2O_5 ha^{-1}, as compared to 10 in P_2O_5 ha^{-1} in the growth chamber (Tables 3, 4, 5, and 6). Interestingly, canola and flax appeared more sensitive in the laboratory study than in the growth chamber (Tables 3, 4, 5, and 6). In the laboratory study, statistically significant emergence reduction compared to the

control was observed above 20 kg P_2O_5 ha^{-1} , which supports the current guidelines. In the lab study, as in the growth chamber study, the oriental mustard (B. juncea) appeared to be more sensitive to seed placed P than canola. Any differences in relative tolerance of crops between the growth chamber and lab study could be a reflection of differential impacts of surface moisture fluctuations. However, with the exception of canola and flax, the general trend as to how the seed-placed P affected germination and emergence of crops tested was similar in growth chamber and lab.

Table 6. Emergence as affected by different rate of P fertilizer for bromegrass, alfalfa, pinto bean, chickpea and yellow pea from the laboratory study

Rate of fertilizer kg P_2O_5 ha^{-1}	Bromegrass		Alfalfa		Pinto bean		Chickpea		Yellow pea	
	Counts	% E* %	Counts	% E* %	Counts	% E* %	Counts	% E* %	Counts	% E* %
0	22.8a	76a	14.3a	71a	7.5ab	94ab	6.0a	75a	7.8a	97a
10	22.8a	76a	14.0a	70a	7.3b	91ab	3.8b	47b	6.0ab	76ab
20	20.0a	67ab	13.3a	66a	8.0a	100a	5.5a	69a	6.0ab	75ab
30	20.8a	69ab	10.8b	54b	6.5b	81b	4.8ab	60ab	5.8b	72b
40	19.8ab	66bc	9.0b	45b	6.5b	81b	4.8ab	60ab	4.5b	56b
60	16.8b	56c	5.3c	26c	3.5c	44c	0.8c	10c	2.3c	28c
80	12.5c	42d	2.3d	11d	2.5c	31c	0.8c	10c	1.5c	19c

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
* %E (% Emergence) refers to % of planted seeds that emerged over 10 days

Effect of P Fertilizer Rate on Plant Dry Matter Yield In the Growth Chamber

Good yield response to the seed-placed P in the first 4 weeks of growth was achieved in the crops (Tables 7 and 8) up to the point where injury was observed in the mustard, bromegrass, alfalfa and pea (Tables 3 and 4). In the case of bromegrass, dry matter yield at rate of 40 kg P ha^{-1} dropped back to a similar value to that with no P addition, and is explained as a result of injury to the stand (Table 4). A similar reason explains the negative response trend in the treatments of mustard and

yellow pea to the seed-placed P, as injury to the stand was observed in these crops at higher rate of P fertilizer (Tables 3 and 4). With the exception of chickpea, pinto bean and mustard, all crops responded significantly in early growth to seed-placed P with responses in sensitive crops limited by injury at high rates. One can note that despite injury reducing the total plant yield in some instances, the weight of individual plants is generally increased by P addition. Also of note is the lack of statistically significant response of the grain legume crops to P, likely due to higher variability in yield among reps in these crops.

Table 7. Dry matter yield (4 weeks after emergence) as affected by 5 different rate of seed-placed P fertilizer for wheat, canary, canola, mustard and flax.

Rate of	Wheat		Canary		Canola		Mustard		Flax	
fertilizer	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*
kg P_2O_5 ha^{-1}	g	mg	g	mg	g	mg	g	mg	g	mg
0	0.87a	74a	0.33a	16a	0.97a	84a	0.84a	89a	0.18a	19a
10	1.02a	88ab	0.31a	17ab	1.21abc	105ab	0.73a	95a	0.17a	18a
20	1.06a	95bc	0.39ab	21bc	1.16ab	110ab	0.92a	118a	0.19a	22ab
30	1.12ab	97bc	0.39ab	22c	1.49c	134b	0.67a	135a	0.28b	27bc
40	1.21b	108c	0.44b	23c	1.38bc	124b	0.66a	137a	0.27b	32c

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
*/In.P = mean weight of individual plants in each treatment

Table 8. Dry matter yield (4 weeks after emergence) as affected by 5 different rates of seed-placed P fertilizer for bromegrass, alfalfa, pinto bean, chickpea and yellow pea.

Rate of fertilizer	Bromegrass		Alfalfa		Pinto bean		Chickpea		Yellow pea	
	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*
kg P_2O_5 ha^{-1}	g	mg	g	mg	g	mg	g	mg	g	mg
0	0.08a	5a	0.20a	14a	1.19a	184 a	0.78a	158a	0.67ab	93a
10	0.24b	18b	0.36c	23ab	1.18a	193a	0.86a	143a	0.71b	95a
20	0.18ab	15ab	0.32bc	26b	1.24a	199a	0.65a	131a	0.44a	96a
30	0.25b	17b	0.31abc	30b	1.44a	208a	0.57a	127a	0.44a	108a
40	0.09a	12a	0.23ab	22ab	1.34a	223a	0.76a	164a	0.44a	113a

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
*/In.P = mean weight of individual plants in each treatment

Effect of P Fertilizer Rate on Plant P Uptake

Table 9. Seedling P uptake (4 weeks after emergence) as affected by 5 different rate of seed-placed P fertilizer for wheat, canary, canola, and mustard.

Rate of fertilizer	Wheat		Canary		Canola		Mustard	
	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*
kg P_2O_5 ha^{-1}	g	mg	g	mg	g	mg	g	mg
0	1.60c	136d	1.32c	113d	0.59b	64b	2.00a	280a
10	2.65b	231c	1.92b	164cd	0.58b	63b	2.06a	274a
20	3.05b	272bc	2.06b	207bc	0.66b	76b	1.44a	311a
30	3.60a	314ab	3.16a	290a	1.00a	97a	1.41a	339a
40	3.83a	342a	2.97a	256ab	0.98a	115a	1.49a	365a

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
*/In.P = mean weight of individual plants in each treatment

Plant P uptake in the first 4 weeks of growth in response to the seed-placed P showed the expected general effect of increased P uptake with increased rate of P addition (Tables 9 and 10). This was most evident in wheat, canary and canola as these crops were not sensitive to injury at

rates up to 30-40 kg P_2O_5 ha^{-1}. Mustard, alfalfa and pinto bean did not significantly respond to the added P in increased P uptake nor were they responsive in dry matter yield. Yellow field pea did respond to the first rate increment of 10 kg P_2O_5 ha^{-1} but thereafter uptake was similar. It would appear that early P nutrition is perhaps most important for cereals like wheat and canary seed.

Table 10. Seedling P uptake (4 weeks after emergence) as affected by 5 different rates of seed-placed P fertilizer for alfalfa, pinto bean, chickpea and yellow pea.

Rate of fertilizer	Alfalfa		Pinto bean		Chickpea		Yellow pea	
	Total	/In.P*	Total	/In.P*	Total	/ In.P*	Total	/In.P*
kg P_2O_5 ha^{-1}	g	mg	g	mg	g	mg	g	mg
0	2.70a	449b	4.85a	989a	0.23c	15b	0.42b	29b
10	3.04a	482ab	3.68a	720a	0.87a	65a	0.91a	59ab
20	2.68a	466ab	3.32a	672a	0.71ab	62a	0.88a	73a
30	3.50a	529ab	3.18a	796a	0.77ab	54ab	0.82ab	81a
40	3.72a	588a	4.29a	954a	0.34 bc	43ab	0.65ab	62ab

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
*/In.P = mean weight of individual plants in each treatment

In the case of alfalfa, and chickpea and yellow pea there were no significant changes in total P uptake among the different rates of P addition (Tables 9 and 10), and is a reflection of reduction of seedlings from injury at higher rates. Increase in P uptake was actually observed when the calculation was based on P uptake by the individual seedling (Tables 9 and 10). A similar trend was also observed in the mustard plants. Data on flax and bromegrass were not statistically analyzed due to lack of sufficient replicates. The addition of P fertilizer enhanced N uptake as expected (Appendices 1 and 2), up to the point where injury was observed in some crops. Of note is the positive effect that P fertilizer had on N uptake in the legume crop, particularly the chickpea and field pea. This likely is a manifestation of the positive effect of P fertilization on N fixation in these crops.

CONCLUSION and RECOMMENDATIONS

The majority of crops tested in the growth chamber with alternate wetting and drying showed no negative impact on seed germination and emergence with seed-placed P fertilizer at rates of 20 kg P_2O_5 ha^{-1} or less. Optimum conditions of soil moisture generally produced more tolerance to seed-placed P. The following general sensitivity/safety rating of crops to seed row-placed P under the conditions of this study can be made in order of greatest tolerance to least:

wheat $\geq$ canaryseed > pintobean $\geq$ chickpea > canola $\geq$ mustard, flax $\geq$ bromegrass> alfalfa $\geq$ pea.

Max ~ 40 kg P_2O_5 ha^{-1} 30 P_2O_5 ha^{-1} 20 kg P_2O_5 ha^{-1} 15 kg P_2O_5 ha^{-1}

Future recommended work would be further testing of injury thresholds in the field and evaluation of different P fertilizer forms such as controlled release products and liquid P fertilizers. In the soil used, some seed-placed P appeared useful in promoting early P uptake and growth in nearly all crops tested, with greatest responses in the cereals.

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Appendix 1. Plant N uptake (4 weeks after emergence) as affected by 5 different rate of seed-placed P fertilizer

Rate of fertilizer	Wheat		Canary		Canola		Mustard	
	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*
kg P_2O_5 ha^{-1}	g	mg	g	mg	g	mg	g	mg
0	53b	4.5b	74c	6.4c	14b	1.5c	56a	7.8a
10	63ab	5.5ab	84c	7.2bc	14b	1.5c	60a	8.0a
20	65a	5.8a	84c	8.4b	16b	1.9bc	35b	7.6a
30	66a	5.7ab	118a	10.8a	22a	2.1ab	36b	8.8a
40	72a	6.4c	100b	8.6b	22a	2.6a	34b	8.9a

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
*/In.P = mean weight of individual plants in each treatment

Appendix 2. Plant N uptake (4 weeks after emergence) as affected by 5 different rates of seed-placed P fertilizer.

Rate of fertilizer	Alfalfa		Pinto bean		Chickpea		Yellow pea	
	Total	/In.P*	Total	/In.P*	Total	/In.P*	Total	/In.P*
kg P_2O_5 ha^{-1}	g	mg	g	mg	g	mg	g	mg
0	73a	12.2a	59a	11.8a	6b	0.4b	13b	0.9b
10	82a	13.0a	53a	10.1a	17a	1.3a	25a	1.6ab
20	69a	13.0a	46a	9.5a	14ab	1.2a	22ab	1.8a
30	85a	12.9a	38a	9.5a	17a	1.2a	21ab	2.0a
40	88a	13.8a	50a	11.3a	7b	0.9ab	16b	1.5ab

For each fertilizer source, means in columns followed by a different letter are significantly different at $p < 0.05$.
*/In.P = mean weight of individual plants in each treatment

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Equipment
None

Project Developed Materials

J.J. Schoenau. Fertilizer Placement in Direct Seeding Systems. Presentations at Davidson, Cabri SK Producer Fertility Information Meetings, March 2005.

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